Application Report

Surface Energy Improvement of Medical Plastics

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Industry section: Medicine
Author: Dr. Peter Guschl,
Surfx Technologies LLC
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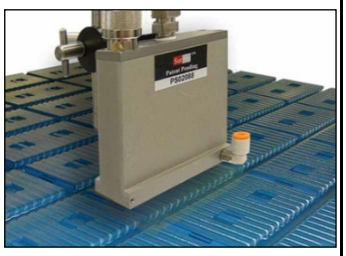
Krüss EasyDrop Contact Angle Measuring Instrument



Surfx Atomflo™ 2" linear plasma head

Method:

Keywords: Atmospheric plasma, surface treatment, medical plastics, water contact angle, surface energy, hydrophilicity, medicine

The Effect of an Oxygen-Helium Atmospheric Plasma on the Surface Energy of Medical Plastics

Abstract

Many plastics possess physical properties that are desirable to the medical industry. By allowing these medical plastics to bond well with other plastics or materials of interest, more convenient and functional medical devices can be fabricated and applied. However, most polymeric materials or plastics do not bond well as they are typically very hydrophobic (water contact angles ~90°) and have low surface energies (~30-50 mN/m). Atmospheric plasma surface treatments are useful for intentionally modifying organic (e.g. polymer, carbon fibers, etc.) or inorganic (e.g. metals, glass, etc.) substrates. By increasing the hydrophilic character and, ultimately, the surface energy of plastic substrates, the adhesive strength can be significantly improved when bonded with particular adhesives.

Method

Three non-reinforced medical plastics were selected for testing and received from Boedeker Plastics Inc.: Acetal copolymer (Celcon®), Polycarbonate (Lexan®) and Polyethylene terephthalate (Ertalyte® PET-P).

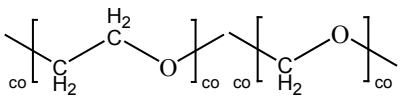
The atmospheric plasma device used for surface modification was a Surfx Atomflo™ system with a 2" linear head (plasma source) with an oxygen-helium plasma.

The KRÜSS EasyDrop Contact Angle Measuring Instrument with the Drop Shape Analysis software was utilized to measure liquid contact angles. Before and after plasma treatment, water and diiodomethane contact angle measurements were made for each sample.

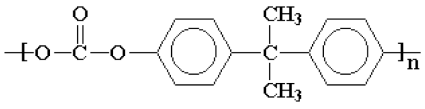
Experimental section

Three plastic materials were subjected to varying durations of oxygen-helium plasma exposure. The chemical structures of the polymers are displayed in Figure 1.

Acetal Copolymer (AC)



Polycarbonate (PC)



Polyethylene Terephthalate (PET)

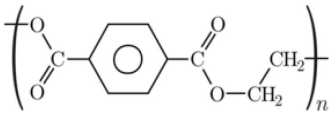


Fig. 1: Chemical structure of the plastics' repeat units

The plasma device was operated under a radio-frequency (RF) power setting of 200 W at 27.12 MHz with oxygen and helium flow rates of 0.90 and 30 L min^{-1}, respectively. An XYZ robot was used to translate the plasma head at a rate of 10 to 100 mm/s over the materials which were affixed to an aluminum stage at a distance of 5 mm from the surface of the sample coupons. The effect of plasma exposure time on each material was evaluated for this study. Exposure time was calculated to be the product of the number of scans and the length of the sample divided by the scan rate.

The contact angle measurements were carried out with approximately 9-12 droplets of each liquid per sample. The Owens, Wendt, Rabel and Kaelble method[1] was applied in order to determine the surface energies of the test materials from the contact angle data.

Results

As a result of the exposures, the wettability of the plastic surfaces was greatly improved. Figure 2 shows the plasma effects on the three materials. All samples exhibited a clear reduction in water contact angle (WCA) within the first 5-10 seconds. Unusually, the WCA of the Acetal copolymer rises after approximately 10 s from ~46 to 64°. The AC material undergoes oxidation through reaction of only the hydrogen atoms of the methylene (–CH_2–) groups of the polymer backbone. Once the polymer chains are saturated with oxygen atoms from the plasma, further exposure causes the polymer chains to degrade into carbon dioxide (CO_2) and possibly other oxidized hydrocarbon compounds. We believe that this "etching effect" generates fresh AC surfaces that raise the average WCA of the sample.

Conversely, the PC and PET WCA values continue to decrease towards steady state values. These polymers consist of two types of groups that can be oxidized: main chain and aromatic. It is possible that etching could happen beyond 40 seconds for these materials once full oxygen saturation occurs. Further investigation of the surface functionalities of the surfaces after specific plasma exposures could confirm this hypothesis.

A Langmuir adsorption model was assumed in order to explain the behavior of the improved surface energy of the plastic surfaces. Figure 3 displays the calculated data for surface energy along with the curve fits. Overall the data and model agree adequately. However, some disparity arises for long exposure times, especially for AC where the supposed "etching effect" is not covered by the assumptions of the Langmuir model.

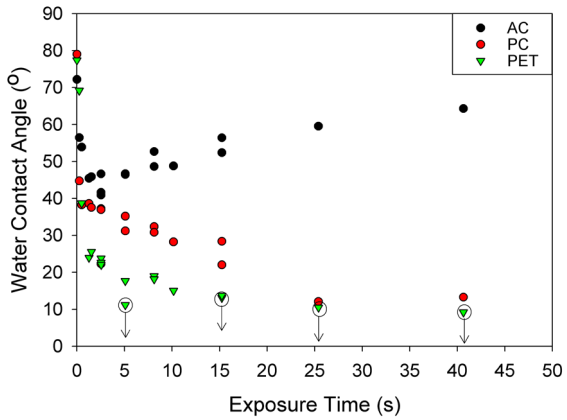


Fig. 2: Water contact angle versus plasma exposure time of AC, PC and PET at 200W (0.90 L O_2/min and 30 L He/min).

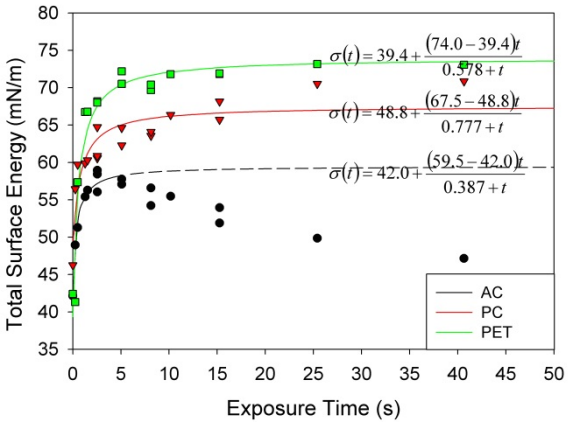


Fig. 3: Model fit of total surface energy versus plasma exposure time of AC, PC and PET at 200W (0.90 L O_2/min and 30 L He/min).

Summary

Atmospheric plasma surface modification effectively improved the hydrophilic character of three initially hydrophobic plastic materials. Each plastic exhibited at least a 36% reduction in water contact angle. The PET showed the largest enhancement in surface energy of approximately 88%. This information can be used to determine the appropriate plasma conditions for adhesion promotion when bonding these plastics with adhesives.

Literature

[1] Estimation of the Surface Energy of Polymers; DK Owens, RC Wendt; Journal of Applied Polymer Science, Vol 13, 1969, 1741-1747

[2] www.kruss.info/service/lit/surface_energy_solids_e.html

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